NWS EHB 6-539

# OPERATOR HANDBOOK

# OPEN PRINCIPAL USER PROCESSOR (OPUP)

# DOPPLER METEOROLOGICAL RADAR WSR-88D


OFFICE OF PRIMARY RESPONSIBILITY:
NATIONAL WEATHER SERVICE RADAR OPERATIONS CENTER



PUBLISHED UNDER AUTHORITY OF THE SECRETARIES OF
COMMERCE, THE AIR FORCE, AND THE NAVY

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## REFERENCE CARDS

# REFERENCE CARD 01

## WSR-88D FIELD SUPPORT HOTLINE

The WSR-88D Field Support Hotline is located at the Radar Operations Center in Norman, Oklahoma. The Hotline operates 24 hours a day, 7 days a week to support all field sites and Government users.

### HOTLINE COMMUNICATION
(VIA TELEPHONE)

**TOLL FREE**
**1-800-643-3363**

**FTS and Commercial**
**(405) 366-2980**

(VIA FACSIMILE)

**(405) 366-2958**

(VIA FAXBACK)

**1-800-874-6745**
**or (405) 366-6559**

(VIA INTERNET)

**http://www.roc.noaa.gov/ops/hotline.asp**

### SERVICES PROVIDED

Timely, expert advice to field sites and Government users:

- **INTERPRETATION**
- **OPERATION**
- **MAINTENANCE**
- **SOFTWARE**
- **ADAPTATION DATA**
- **COMMUNICATIONS**
- **DOCUMENTATION**

### SUPPORT LIMITATIONS

Field sites should consider information provided by the Hotline only as guidance which does not supersede any agency or local policies, procedures, and regulations. Hotline operations specialists, for example, will not normally advise a field site whether or not to issue a weather warning. Instead, the operations specialist will advise the field site how to access and apply the most effective products for the existing weather situation.

### SERVICES PROVIDED

Hotline specialists rank incoming assistance requests as follows:

**URGENT**

Assistance in resolving conditions that may cause death, severe injury, major system damage, or prevent successful mission accomplishment

**ROUTINE**

Assistance in resolving conditions that do not meet urgent priority guidelines.

### INFORMATION YOU SHOULD PROVIDE

Description of problem
Circumstances leading to the problem
Effects on operations
Other pertinent information
Point of contact (optional)

# REFERENCE CARD 02

## WSR-88D RECORDING LEVELS

### RECORDING LEVEL I

LOCATION..... RDA

DATA TYPE ..... Raw analog signal (time-domain)

RECORDING MEDIA .... Undetermined

AVAILABILITY..... Port available at all RDA sites

USAGE ..... Maintenance personnel only

Archive Level I data are the analog, time-domain outputs of the receiver. Information on synchronization, calibration, date, time, antenna position, and status is also available.

### RECORDING LEVEL III

LOCATION ..... RPG

DATA TYPE..... Selected RPG-generated products

RECORDING MEDIA..... Electronic transfer to NCDC

AVAILABILITY ..... All RPGs

USAGE ..... NCDC archive for data at radar network sites (products predetermined by Agency); training

Archive Level III data are the outputs of the RPG including system status information and selected products generated by the RPG.

### RECORDING LEVEL II

LOCATION ..... RDA

DATA TYPE..... Digital data output of the signal processor

RECORDING MEDIA.... Electronic transfer to NCDC

AVAILABILITY .....All RDAs

USAGE.....ROC maintenance and development activities; displaced real time playback (training); data collection for analysis activities

Archive Level II data are the digital base outputs of the signal processor. Information on synchronization, calibration, date, time, antenna position, status, and operational mode is also available.

### RECORDING LEVEL IV

LOCATION .....OPUP
DATA TYPE.....Any product available at the OPUP
RECORDING MEDIA.....CD ROM
AVAILABILITY .....All OPUPs.
USAGE.....Any required purpose

Archive Level IV is any data or information available at the OPUP.

# REFERENCE CARD 03

## MESOCYCLONE RECOGNITION GUIDELINES

**NOTE** These values were derived for the Oklahoma City, OK area. Use these values as general guidelines only; values for your area may differ.

### GENERAL

A MESOCYCLONE exists if all the listed observations are made in association with the updraft portion of a storm.

### OBSERVATIONS

**ROTATIONAL VELOCITY ($V_r$):**
$V_r = ( |V_{in}| + |V_{out}| ) / 2$
**(See REFERENCE CARD 21)**

**CORE DIAMETER:** $\leq$ 5 nmi.

**VERTICAL EXTENT:**
Rotation extends at least 10,000 ft. (**Caution:** may be less for mini-supercells.)

**TIME CONTINUITY:**
Circulation signature must persist at least two successive volume scans.

### MESOCYCLONE RECOGNITION

Feature is a MESOCYCLONE if:

Rotational Velocity is $\geq$ 25 knots at a range of 5 nmi from the radar, **decreasing** to $\geq$ 17 knots at 124 nmi from the radar. **(See REFERENCE CARD 5)**

CORE DIAMETER, VERTICAL EXTENT, and TIME CONTINUITY observation criteria are met.

**CAUTION**

Use other data sources, such as 3-D reflectivity data, environmental characteristics, spotters, to help determine if a tornado warning condition exists.

### STRONG MESOCYCLONE RECOGNITION

Feature is a STRONG MESOCYCLONE if:

ROTATIONAL VELOCITY is $\geq$ 45 knots at a range of 5 nmi from radar, **decreasing** to 33 knots at 124 nmi from the radar. **(See REFERENCE CARD 5)**

CORE DIAMETER, VERTICAL EXTENT, and TIME CONTINUITY observation criteria are met.

# REFERENCE CARD 04

## TORNADIC VORTEX SIGNATURE RECOGNITION CRITERIA

**NOTE** These values were derived for the Oklahoma City, OK area. Use these values as general guidelines only; values for your area may differ.

### GENERAL

A TORNADIC VORTEX SIGNATURE (TVS) exists if all of the listed observations are made within a mesocyclone.

### OBSERVATIONS

**AZIMUTHAL SHEAR:** Azimuth-to-azimuth (gate to gate) difference between maximum inbound and maximum outbound velocity is $\geq$ 90 knots within 30 nmi or $\geq$ 70 knots from 30 to 55 nmi. Azimuthal Shears = $|V_{in}| + |V_{out}|$

**VERTICAL EXTENT:** Rotation extends several thousand feet, or through at least two elevation angles.

**TIME CONTINUITY:** Rotation persists for at least two consecutive volume scans. **Caution:** Vertical extent and time continuity criteria do not necessarily have to be met for confident TVS recognition. Shear is the most important criterion.

**NOTE** A tornado may or may not be associated with a pre-existing MESOCYCLONE; however, most strong or violent tornadoes are preceded by a strong MESOCYCLONE. **(See REFERENCE CARD 5**)

**CAUTION**

Use other sources, such as 3-D reflectivity data, environmental characteristics, spotters, to help determine if a tornado warning condition exists.

**REFERENCE**

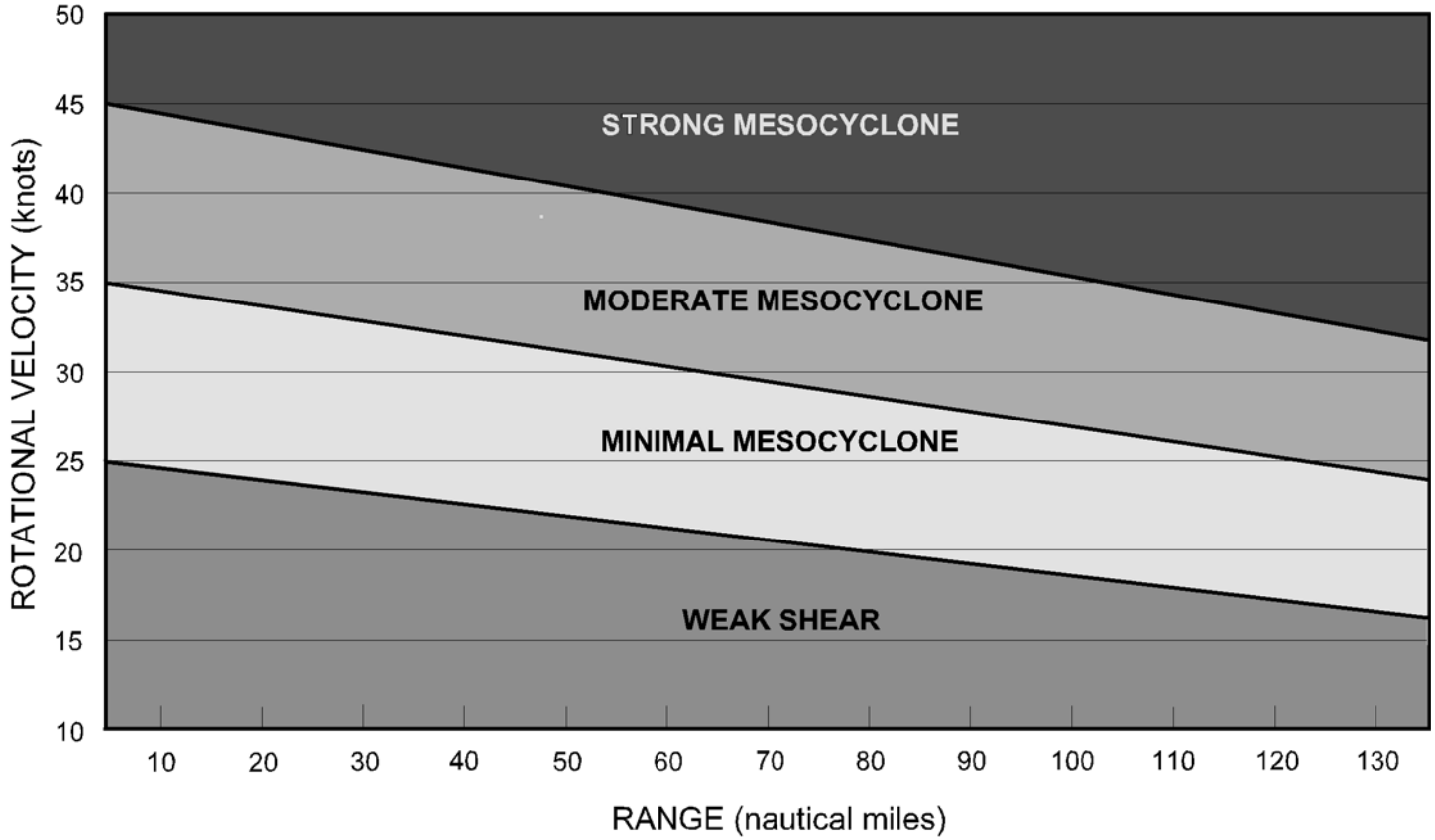
For additional information see Tornado Warning Guidance at http://wdtb.noaa.gov/resources/papers/twg02/twg2002.pdf.

# REFERENCE CARD 05

## SUGGESTED MESOCYCLONE ROTATIONAL VELOCITY THRESHOLD CHART

### (ORIGINATING FROM THE NATIONAL WEATHER SERVICE FORECAST OFFICE, NORMAN, OK)

**NOTE** These values were derived for the Oklahoma City, OK area. Use these values as general guidelines only; values for your area may differ.
Derived from climatological mesocyclone as Rankine Vortex with 1 degree beamwidth; assumes a mesocyclone core diameter of 3.5 nm.



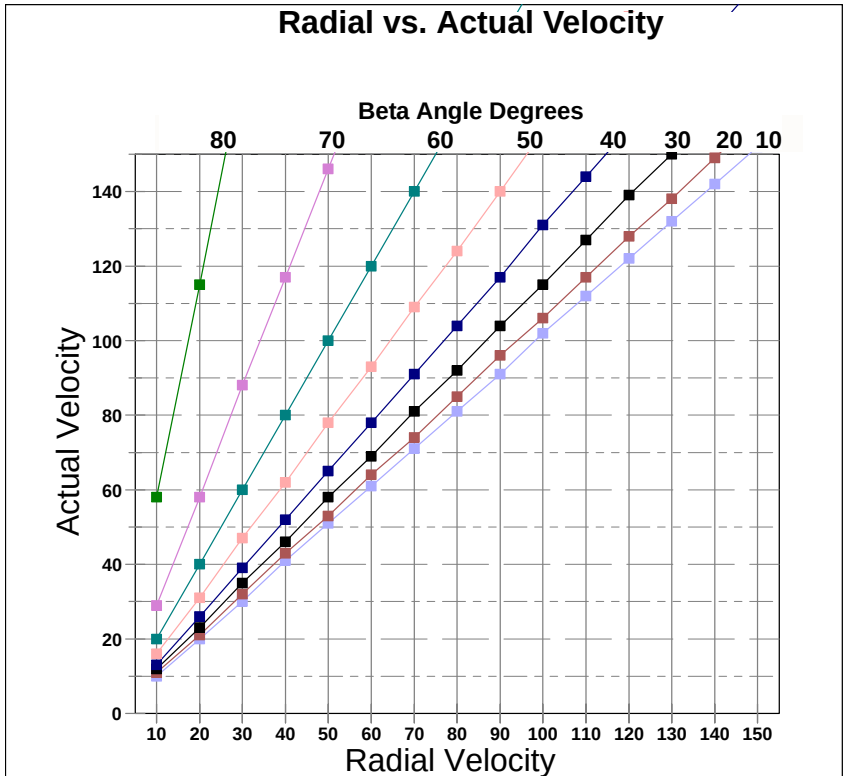

ROTATIONAL VELOCITY: $V_r = ( |V_{in}| + |V_{out}| ) / 2$, use mid-range values.

Feature must have Time Continuity (two consecutive volume scans) and Vertical Extent (10,000 ft.).

# REFERENCE CARD 06

## CONVERSION CHART (radial to actual velocity) (1 of 4)

This nomogram provides an easy way to estimate the ambient wind speed based on the estimated wind direction and radial velocity.




To use the nomogram, interpret the radial velocity from the WSR-88D velocity product and calculate the Beta Angle (based on the estimated wind direction and radar viewing angle, refer to the next page for assistance). Follow the vertical line up from the Radial Velocity speed until it intersects the Beta Angle diagonal line. From this intersection point, read the Actual Velocity value on the scale corresponding to the horizontal grid line.

# REFERENCE CARD 06

## CONVERSION CHART (radial to actual velocity) (2 of 4)

To estimate the wind speed you must determine the ambient wind direction.

The WSR-88D velocity products provide radial velocity estimates. ***Radial Velocity*** is defined simply as the component of target motion ***parallel*** to the radar radial (azimuth). It is that component of a target's motion that is either ***toward*** or ***away*** from the radar site along the radial.

Two methods are provided to assist you in determining the ambient wind direction.

Method 1: A zero isodop with inbound velocities on one side and outbound velocities on the other normally indicates a wind direction perpendicular to the radar azimuth (radar viewing angle).

Method 2: Draw a line along a radar azimuth from the RDA to a desired point along the zero isodop. Draw an arrow perpendicular to the line at that point from inbound to outbound. The arrow represents the wind direction, assuming homogeneous flow at the height (range).

Use this wind direction to determine the Beta angle needed in calculating the true wind field.

The Beta angle is the angular difference between the radar viewing angle (azimuth) and the true wind direction (target motion). See Figure 1 for an example.

# REFERENCE CARD 06

## CONVERSION CHART (radial to actual velocity) (3 of 4)

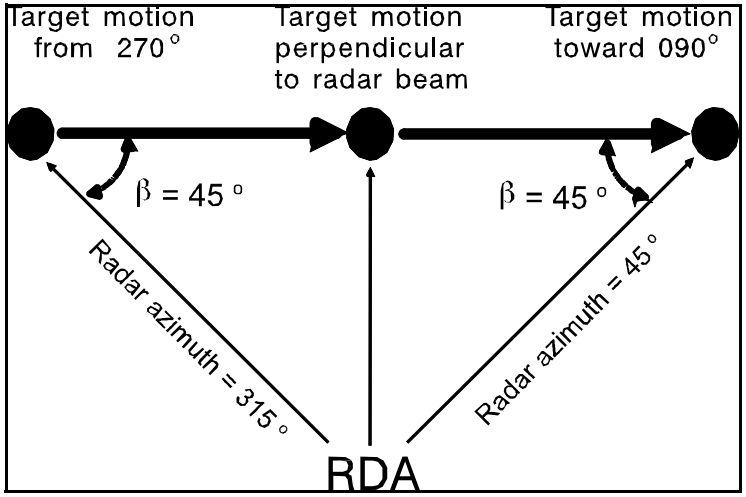



**Figure 1**. As target motion becomes more (less) perpendicular to the radar beam, β increases (decreases). When the target motion is exactly perpendicular to the radar beam β is 90° and the radial velocity is zero.

The angle β (beta) is ***always the smaller*** of the two angles between the radar viewing angle (i.e. radar radial or azimuth) and the actual target velocity vector (***V***).

The relationship between a target's actual velocity and the WSR-88D depicted radial velocity can be described mathematically by using the Radial Speed Equation.

$|V_r| = |V| \bullet \cos \beta$

where:

$V_r$ = radial velocity

$V$ = actual velocity

β = smallest angle between V and the radar radial

cos = cosine

# REFERENCE CARD 06

## CONVERSION CHART (radial to actual velocity) (4 of 4)

When $\beta$ is equal to $0^o$, target motion is parallel to the radar and cos $\beta$ is 1. The target radial speed $|\boldsymbol{V_r}|$ is equal to the actual target speed $|\boldsymbol{V}|$.

When $\beta$ is equal to $90^o$, target motion is perpendicular to the radar beam and cos $\beta$ is zero. The radial speed $|\boldsymbol{V_r}|$ is zero, and there is no component of target motion toward or away from the radar.

The ***greater*** the angle between the target's velocity vector and the radar azimuth, the ***smaller*** the percentage of the target's actual velocity that will be measured and depicted on the Velocity products. The table below shows the relationship between $\beta$ and what percentage of actual target speed is directly measured.

**Percentage of Target Speed Measured**

| $\beta$ degrees | Cosine $\beta$ | Percent Measured |
|---|---|---|
| 0 | 1 | 100 |
| 5 | .996 | 99.6 |
| 10 | .985 | 98.5 |
| 15 | .966 | 96.6 |
| 30 | .866 | 86.8 |
| 45 | .707 | 70.7 |
| 60 | .500 | 50.0 |
| 75 | .259 | 25.9 |
| 90 | 0 | 0 |

# REFERENCE CARD 07

## TANGENTIAL SHEAR (1 OF 2)

**NOTE**: These values were derived for the Oklahoma City, OK area. Use these values as general guidelines only; values for your area may differ.

This reference card defines the calculation to compute tangential shear values, presents thresholds used to identify and classify mesocyclonic rotation and tornadic vortex signatures, and provides an $S_t$ nomogram designed to simplify the operational application of tangential shear values in a time critical, warning environment.

TANGENTIAL SHEAR - Change in velocity divided by distance [$\Delta$V/D]

Add the absolute values of the maximum inbound and outbound velocities (use the mid-range velocity value of the OPUP displayed color level), divided by the distance between them, then convert the result into shear units $^{(s-1)}$.

EXAMPLE: $\frac{58\text{kts} + 39\text{kts}}{5.4\text{nm}} = \frac{97\text{nm/hr}}{5.4\text{nm}} = 17.963/\text{hr} / 3600\ \text{s/hr} = 00499^{s-1} = 4.99\ x10^{-3}\ s^{-1}$

**CAUTION:** Use the beam center points when determining the distance between the maximum inbound and outbound velocities. Since D(distance) is used in the denominator of this calculation, an accurate value is critical to the validity of the shear result. Therefore, great care should be exercised when determining the distance value.

# REFERENCE CARD 07

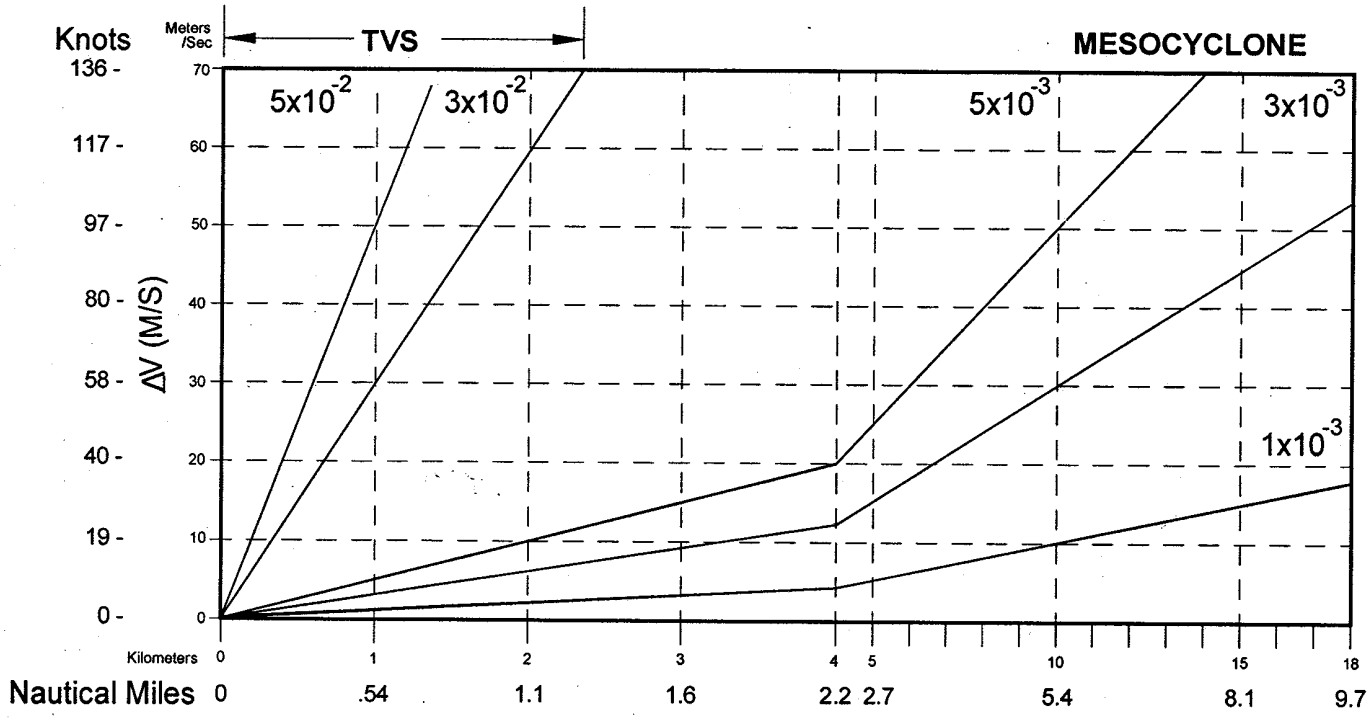
## TANGENTIAL SHEAR (2 OF 2)

**MESOCYCLONE TANGENTIAL SHEAR THRESHOLDS (3 km in height minimum)**

| SHEAR | RANGE |
|---|---|
| $5X10^{-3}S^{-1}$ | <70nm |
| $3X10^{-3}S^{-1}$ | 70 -108 nm |
| $1X10^{-3}S^{-1}$ | >108 nm |

**TORNADIC VORTEX SIGNATURE (TVS) TANGENTIAL SHEAR THRESHOLDS**

| SHEAR | RANGE |
|---|---|
| $5x10^{-2}s^{-1}$ | <27nm |
| $3x10^{-2}s^{-1}$ | >27nm |



# REFERENCE CARD 08

## UPPER LEVEL DIVERGENCE RECOGNITION GUIDELINES
**(ORIGINATING FROM NSSL, NORMAN, OK)**

**NOTE** These values were derived for the Oklahoma City, OK area. Use these values as general guidelines only; values for your area may differ.

### GENERAL

Upper level divergence exists in the upper levels of a convective cell and is indicative of updraft strength. Upper level divergence has been quantitatively related to maximum hailstone size.

### OBSERVATIONS

Maximum velocity difference near storm summit is $\geq$ 75 knots.

Velocity maxima used are not skewed by more than 45 degrees.

**NOTE**

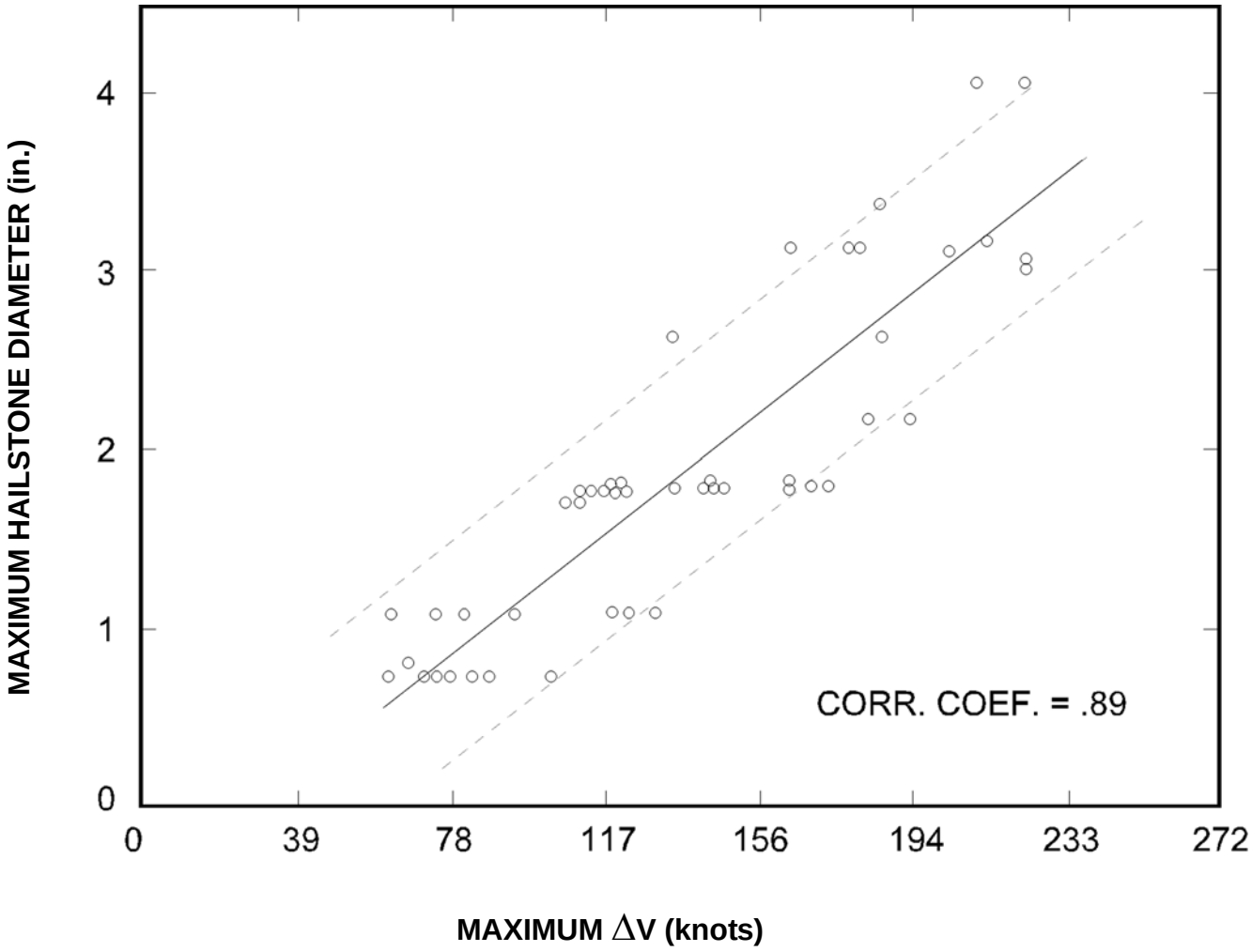
When maximum velocity difference near storm summit is $\geq$ 75 knots, hail diameter often exceeds 3/4 inch (see adjacent hail size difference).

### VELOCITY DIFFERENCE ($\Delta$ V) GUIDELINE VALUES TO HAIL SIZE

| $\Delta$ V (knots) | Max Hail Size |
|---|---|
| 75 - 109 | 3/4” or greater |
| 110 - 135 | Golf Ball |
| 136 - 175 | Tennis ball |
| 176 - 225 | Baseball |
| $\geq$ 226 | Softball/Grapefruit |

# REFERENCE CARD 09

## HAILSTONE DIAMETER vs. MAXIMUM ΔV CHART



# REFERENCE CARD 10

## HAIL INDEX GRAPHIC SYMBOLS

The Hail Index has 4 different Graphic Symbols available. The algorithm calculates the Probability of Hail (POH), the Probability of Severe Hail (POSH), and the Maximum Expected Hail Size (MEHS).

Changes in display thresholds are made at the OPUP.

The radar operator should provide the altitude of the 0 and -20 degree C isotherms at the RPG HCI for this algorithm to provide the most accurate data. If no representative sounding is available, a forecast sounding or one interpolated from the closest sounding may be used. These values must be monitored and updated as Meteorological conditions warrant.


Probability of Hail - Hail of any Size - Minimum Display Threshold (Adaptable)


Probability of Hail - Fill in threshold (Adaptable)


Probability of Severe Hail ≥ 3/4” - Minimum Display Threshold (Adaptable)


Probability of Severe Hail - Fill in threshold (Adaptable)

Maximum Expected Hail Size is displayed to the nearest inch in the center of the POSH symbol from 1 to 4 inches. 

or 

If MEHS is <3/4”, and the POH or POSH is >0%, then an asterisk *, will be displayed in the symbol. 

# REFERENCE CARD 11

## TORNADIC VORTEX SIGNATURE GRAPHIC SYMBOLS

The Tornado Detection Algorithm (TDA) processes velocity data and determines the location, strength, and depth of storm scale circulations. If strength and altitude criteria are met, a circulation is classified as either a Tornadic Vortex Signature (TVS), or an Elevated TVS (ETVS). The Tornadic Vortex Signature (TVS) Product and Overlay have two types of graphic symbols available.

- ▽ ETVS - Base of circulation above 600 meters and 1.0 degree elevation.
- ▼ TVS - Base of circulation at or below 600 meters or 1.0 degree elevation.

The radar operator determines whether or not ETVS symbols are displayed at the PUP. ETVS symbols are toggled on and off using the OPUP Adaptation Data menu.

The TVS Graphic Attribute Table contains the following information:

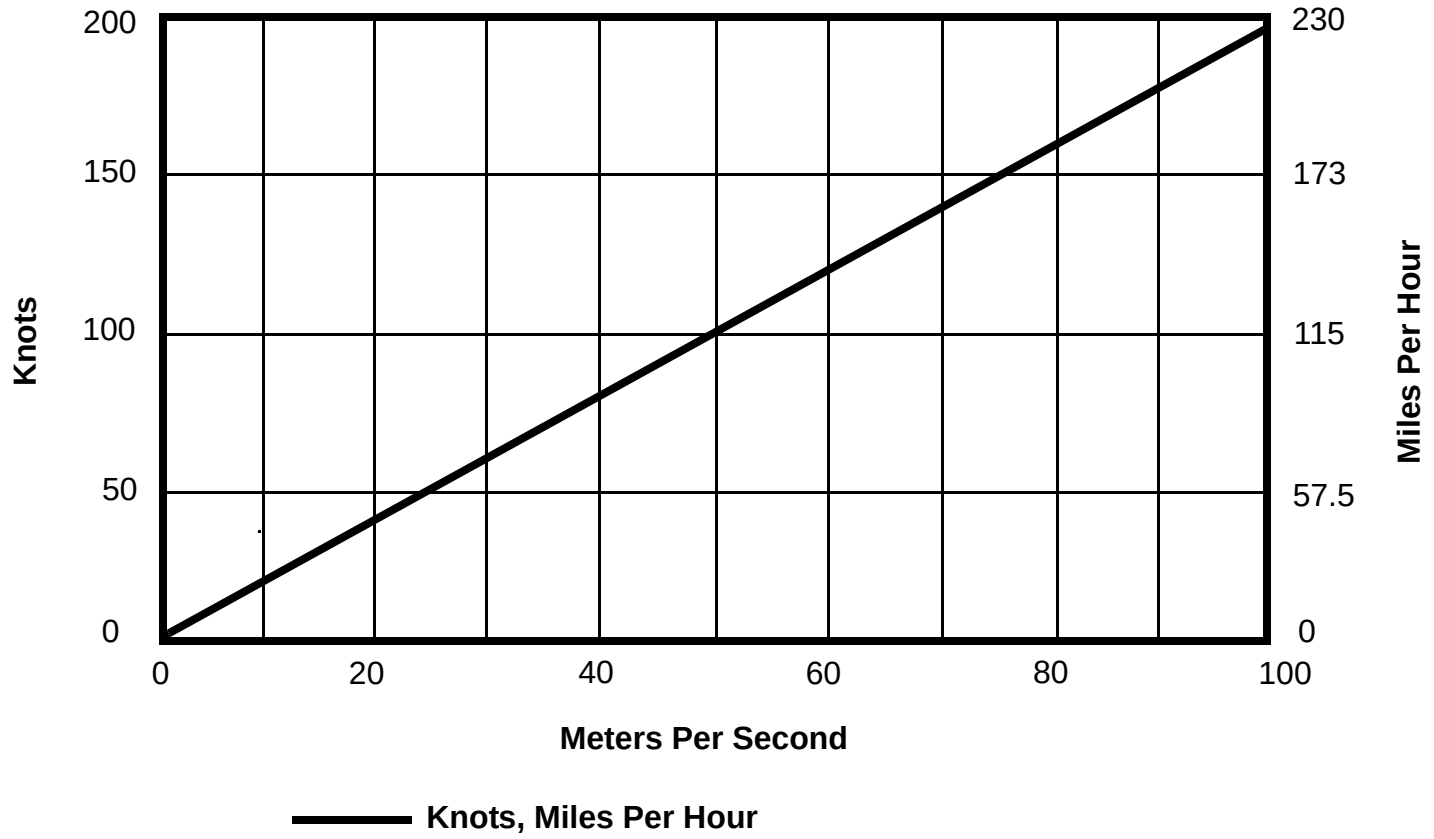
| | |
|---|---|
| TYPE | Type of Feature: TVS or ETVS |
| STID | Storm ID |
| AZ | Azimuth of Circulation (degrees) |
| RAN | Range of Circulation (nm) |
| LLDV | Maximum Low-Level Gate-to-Gate Velocity Difference (kts) |
| MDV | Maximum Gate-to-Gate Velocity Difference (kts) |
| AVGDV | Average Gate-to-Gate Velocity Difference (kts) |
| BASE | Base of Circulation (kft) |
| DPTH | Depth of Circulation (kft) |

# REFERENCE CARD 12

| Convert From | Into | Multiply By |
|---|---|---|
| Meters per second ..... | Miles per hour..... | 2.2369 |
| | Kilometers per hour .. | 3.6 |
| | Knots ..... .. | 1.9438 |
| Knots..... | Kilometers per hour. .. | 1.853 |
| | Meters per second.. .. | 0.51479 |
| | Miles per hour..... .. | 1.1508 |
| Miles per hour ..... | Kilometers per hour. .. | 1.6093 |
| | Knots ..... .. | 0.86839 |
| | Meters per second.. .. | 0.4470 |

## CONVERSION CHART

**(meters per second to knots per hour)**

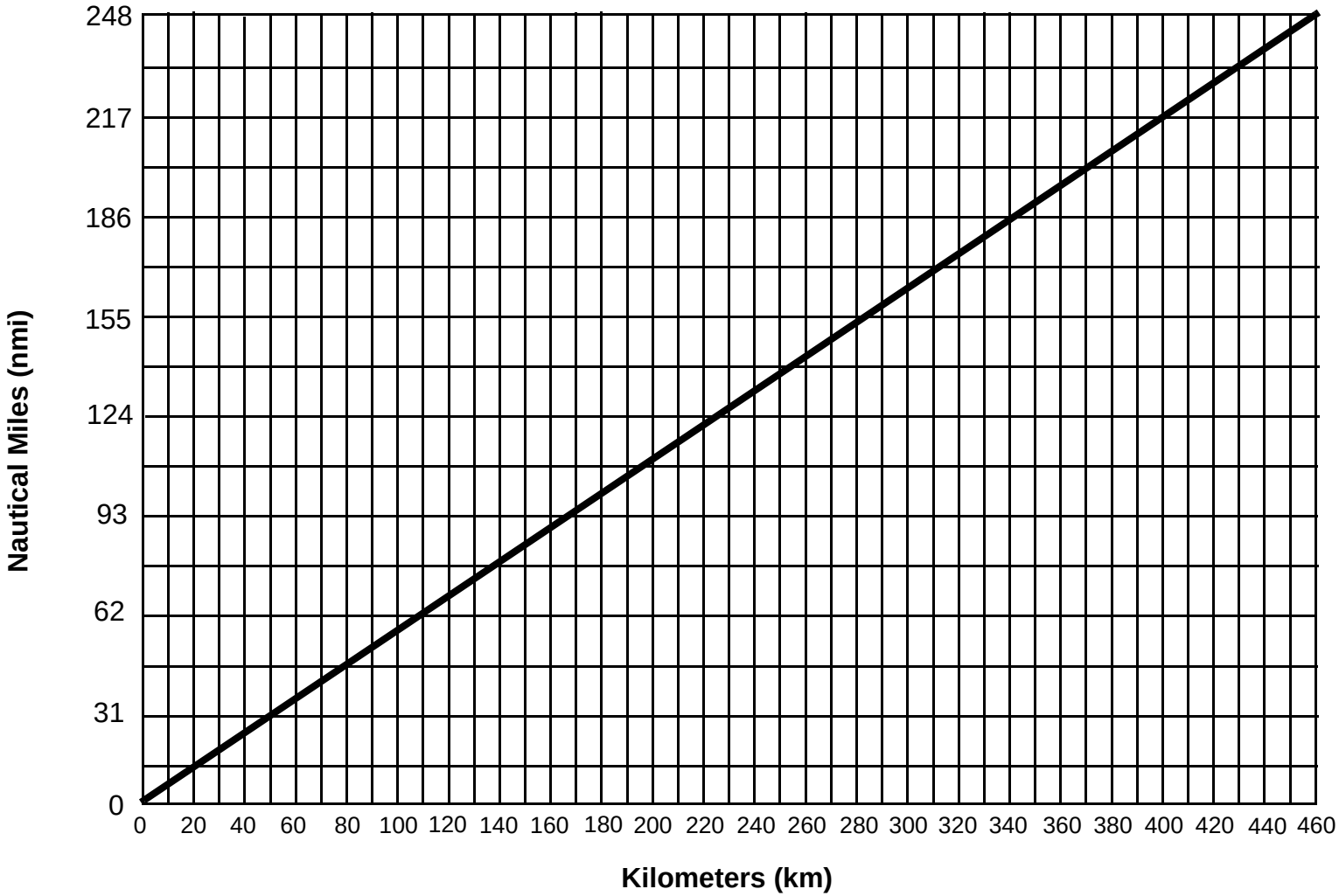


# REFERENCE CARD 13

| Convert From | Into | Multiply By |
|---|---|---|
| Nautical Miles | Kilometers | 1.852 |
| Kilometers | Nautical Miles | 0.53996 |

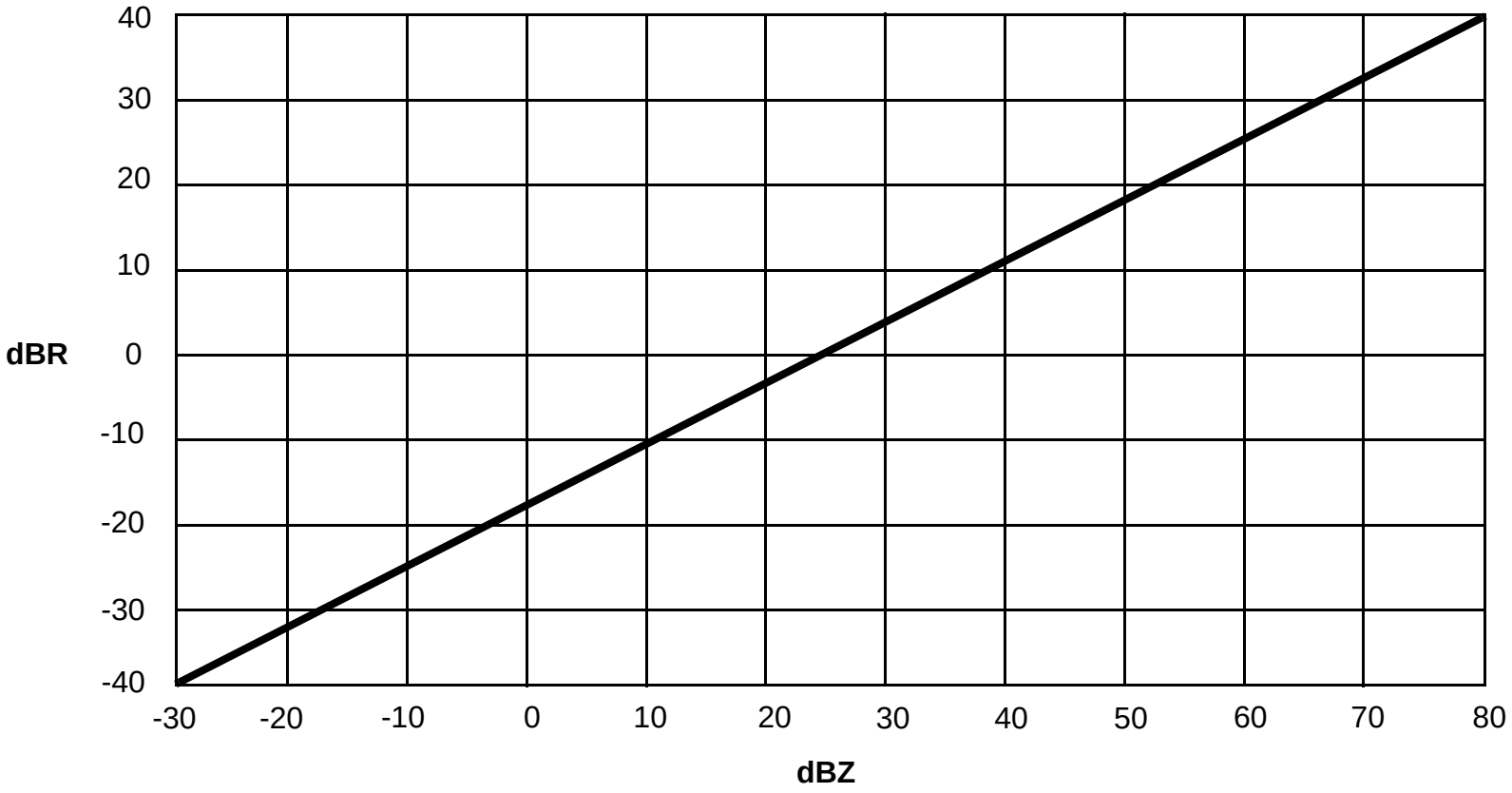
## CONVERSION CHART

**(kilometers to nautical miles)**



# REFERENCE CARD 14

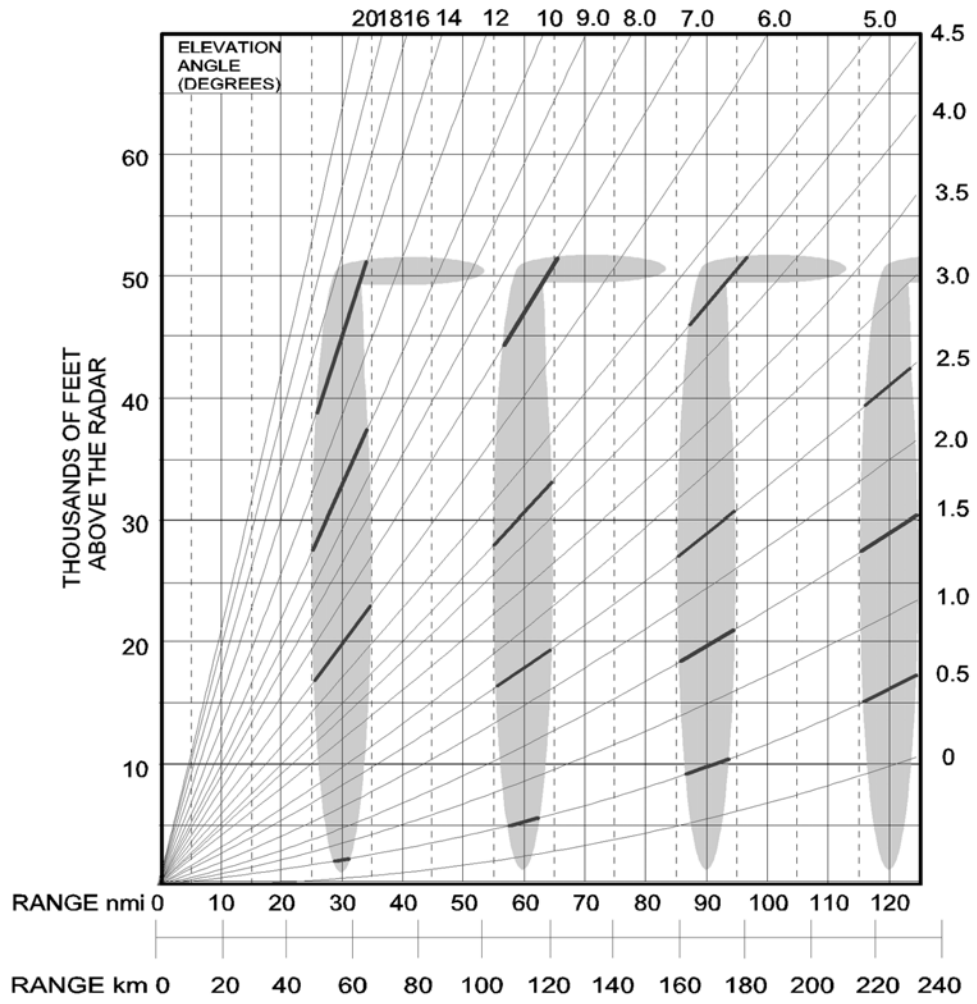
## CONVERSION CHART (dBZ to dBR)




Using $Z=300R^{1.4}$

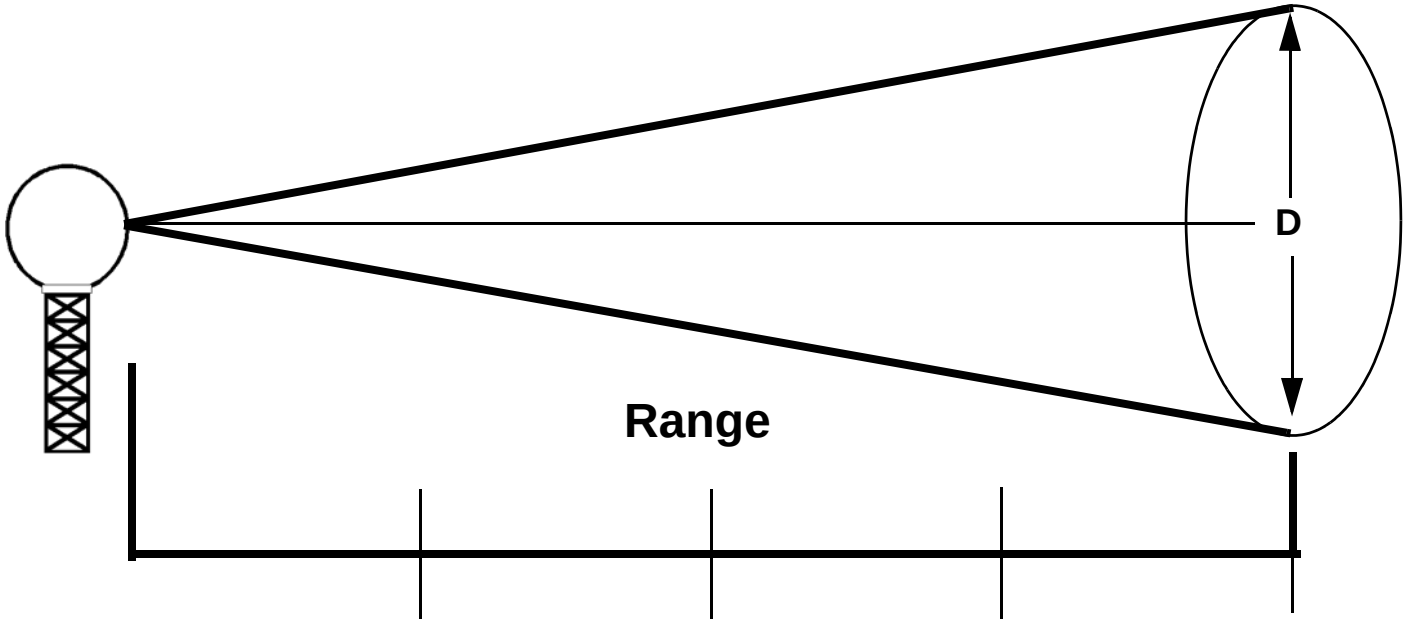
# REFERENCE CARD 15

## BEAM CENTERLINE vs. RANGE



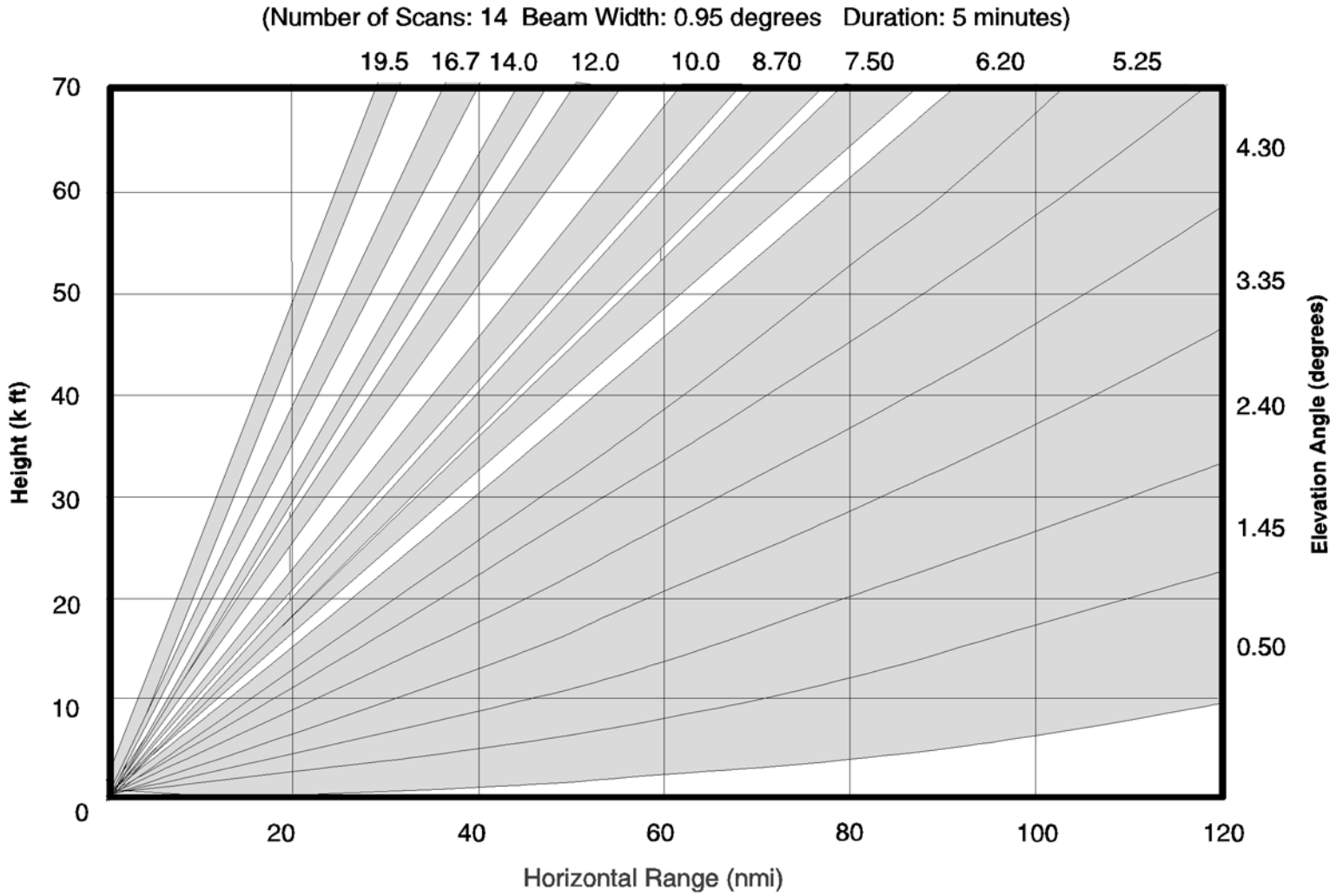
# REFERENCE CARD 16

## WSR-88D BEAM GEOMETRY



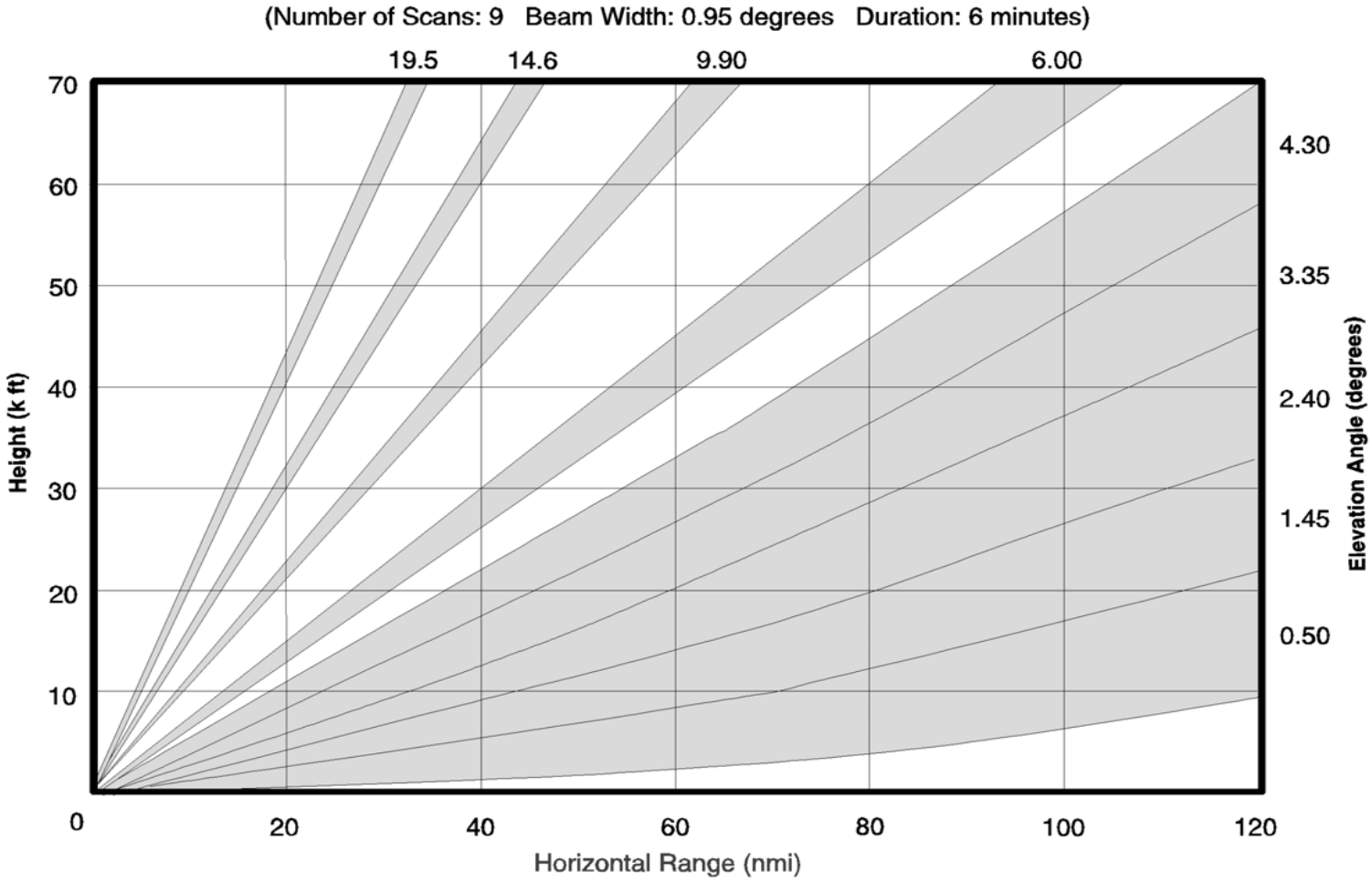
# REFERENCE CARD 17

## VOLUME COVERAGE PATTERN 11



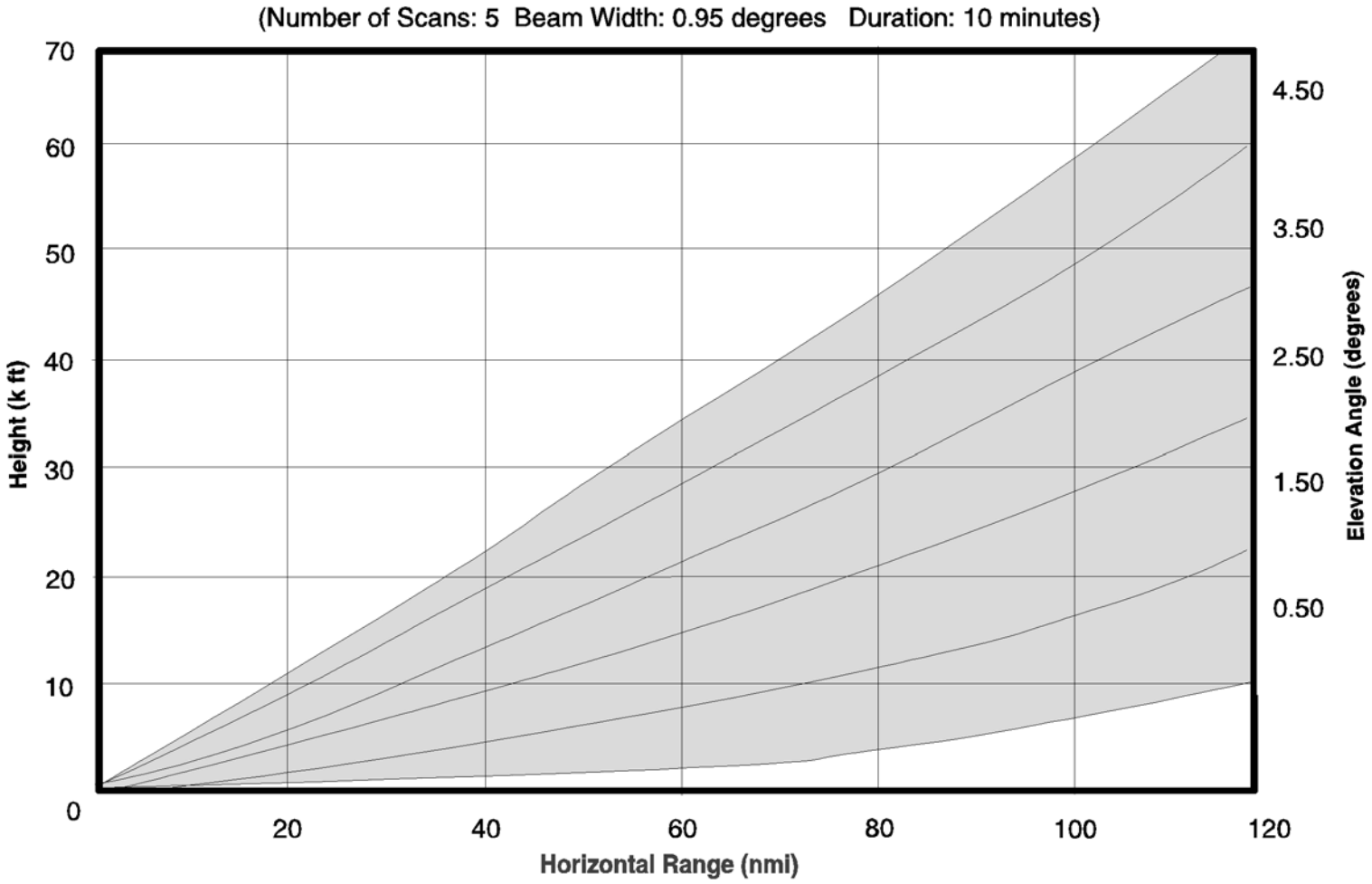
# REFERENCE CARD 18

## VOLUME COVERAGE PATTERN 21



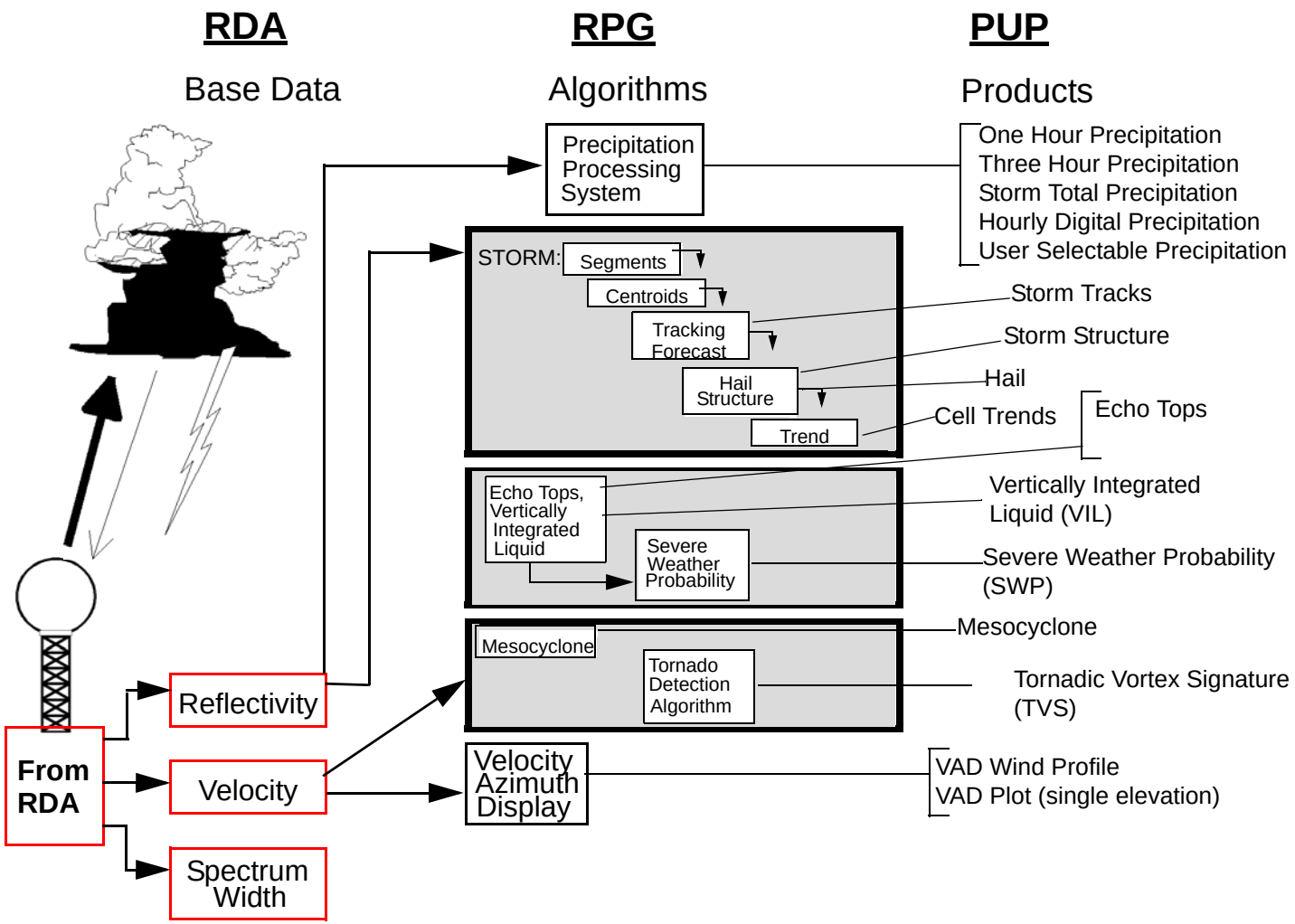
# REFERENCE CARD 19

## VOLUME COVERAGE PATTERN 31/32



# REFERENCE CARD 20

## WSR-88D ALGORITHM FLOWCHART



# REFERENCE CARD 21

## PRF NUMBERS WITH ASSOCIATED UNAMBIGUOUS RANGES

| DOPPLER PRF NUMBER | DELTA PRI NUMBERS (Unambiguous range in nmi, rounded) | | | | |
|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | #5 |
| **4** | 93 | 94 | 94 | 95 | 96 |
| **5** | 79 | 79 | 80 | 80 | 81 |
| **6** | 73 | 73 | 74 | 74 | 75 |
| **7** | 67 | 68 | 69 | 69 | 70 |
| **8** | 62 | 63 | 63 | 64 | 64 |

**NOTE**

**DOPPLER PRF NUMBER** is also known as **PRI NUMBER**

To operate PRF #4 Auto PRF must be off.